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GB 2304838 A EP 0520525 A1 DE 019653961 A
US 5829845 A US 5785157 A US 4567967 A
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(54) Abstract Title
Electromechanical braking system for a motor vehicle

(57) An electromechanical, brake-by-wire braking system for a motor vehicle, comprises control units 12a, 14a, 16a, 18a, responsive to a driver's requirement, for controlling brake actuators 12b, 14b, 16b, 18b each including an electric motor (M_{1H}, Fig.4) and a locking arrangement (Ku_1). For actuating a wheel brake via its electric motor, the locking arrangement is first of all released. The locking arrangement is closed again after actuation has been terminated. The control units are supplied with power from independent sources E_1, E_2. The system is self-diagnostic and in the event of a fault in actuator 12b, a resetting module M_{1R} in the actuator is activated by a signal i_{1R} from control unit 18a, actuators 12b, 18b being on the same axle. In a second system (Fig.6), each control unit controls two actuators, and in a third system (Fig.7), each control unit and actuator receives power from both sources.

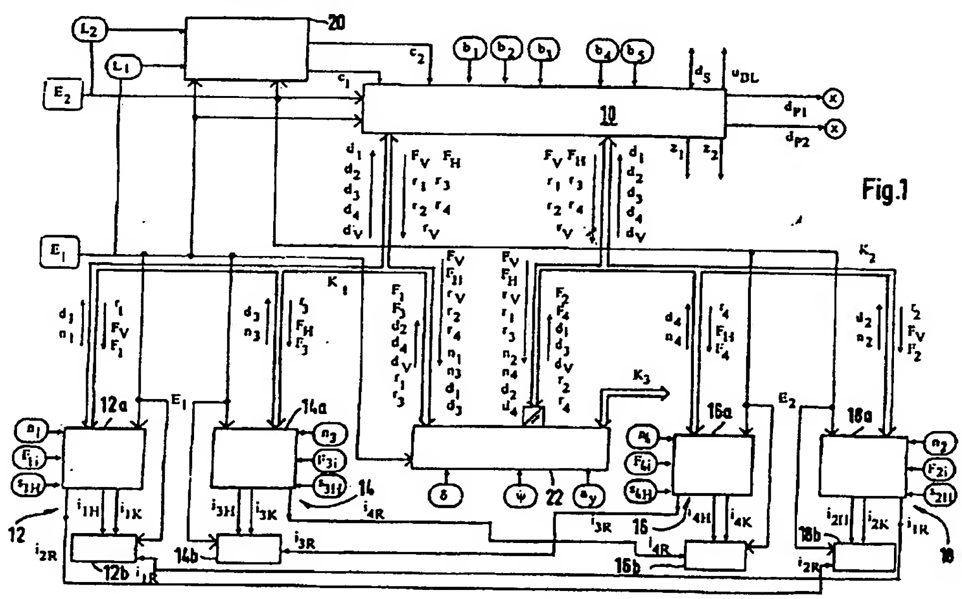

Fig.1

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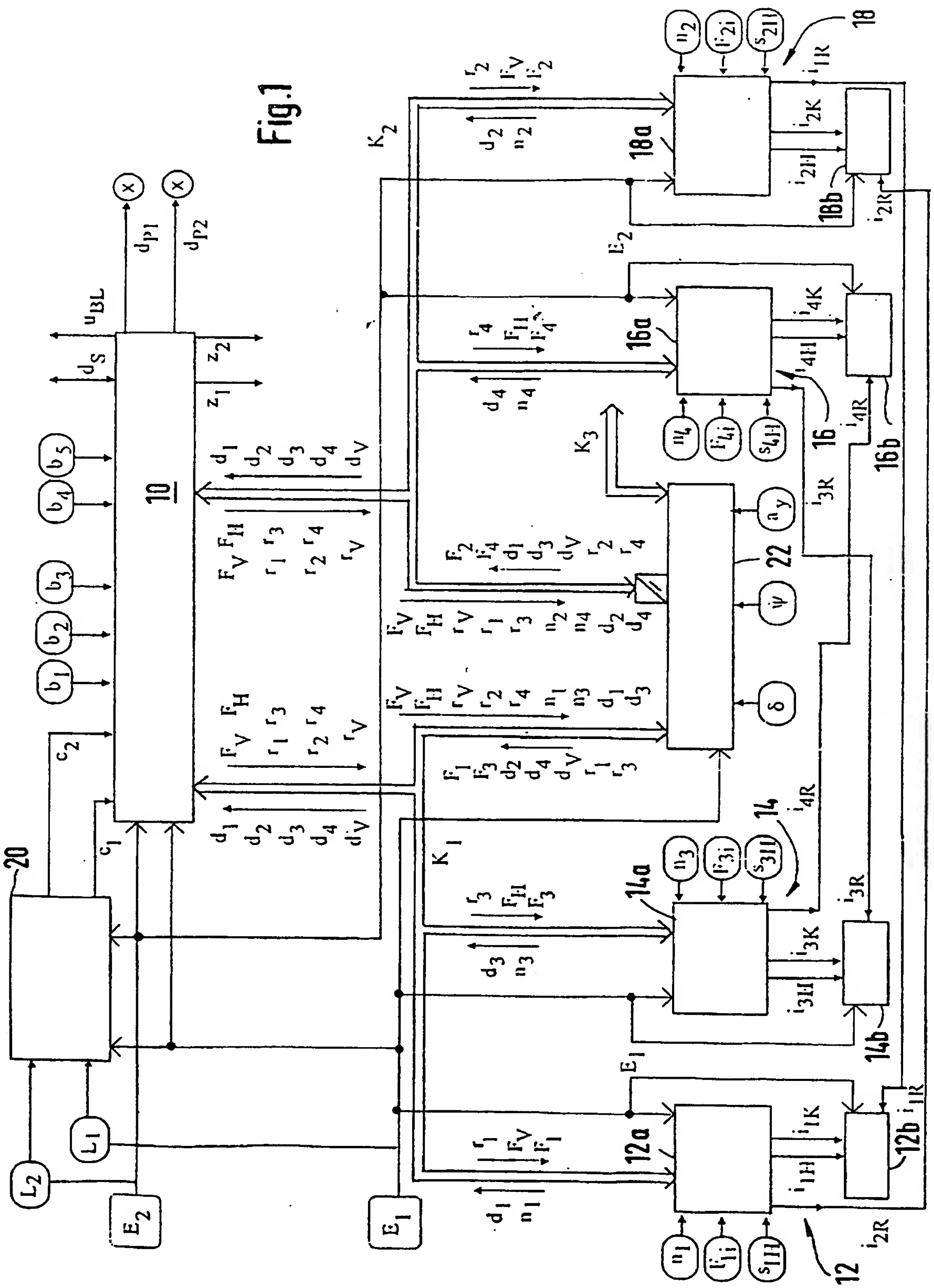
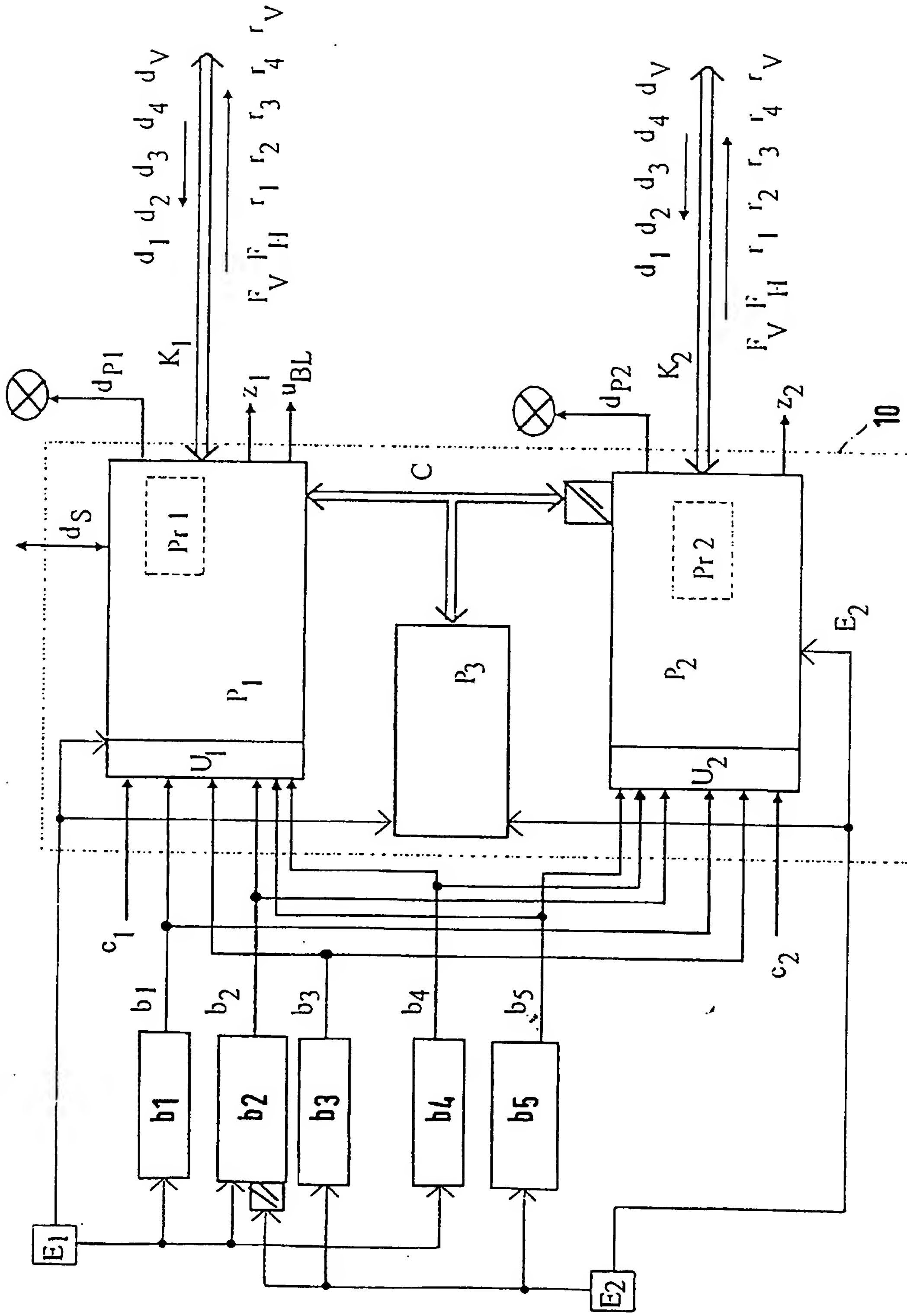


Fig.1
10
12
12a
12b
14
14a
14b
16
16a
16b
18
18a
18b
20
22



d_1 d_2 d_3 d_4 d_V
F_V F_H r_1 r_2 r_3 r_4 r_V
K_1
K_2
d_{P1}
d_{P2}
z_1
u_{BL}
z_2
d_S
C
Pr 1
Pr 2
P_1
P_2
P_3
U_1
U_2
E_2
10
c_1
c_2
b_1 b_2 b_3 b_4 b_5
b1
b2
b3
b4
b5
E1
E2

Fig.2

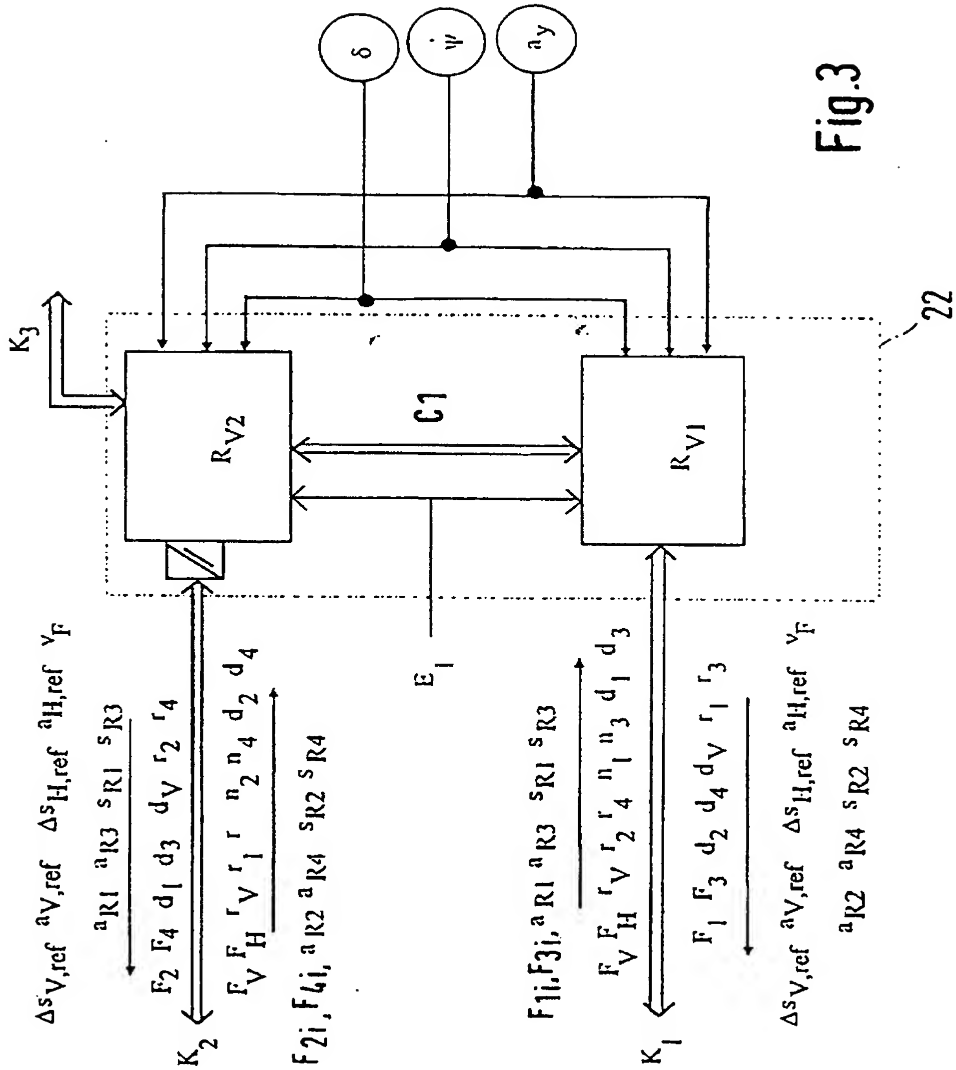
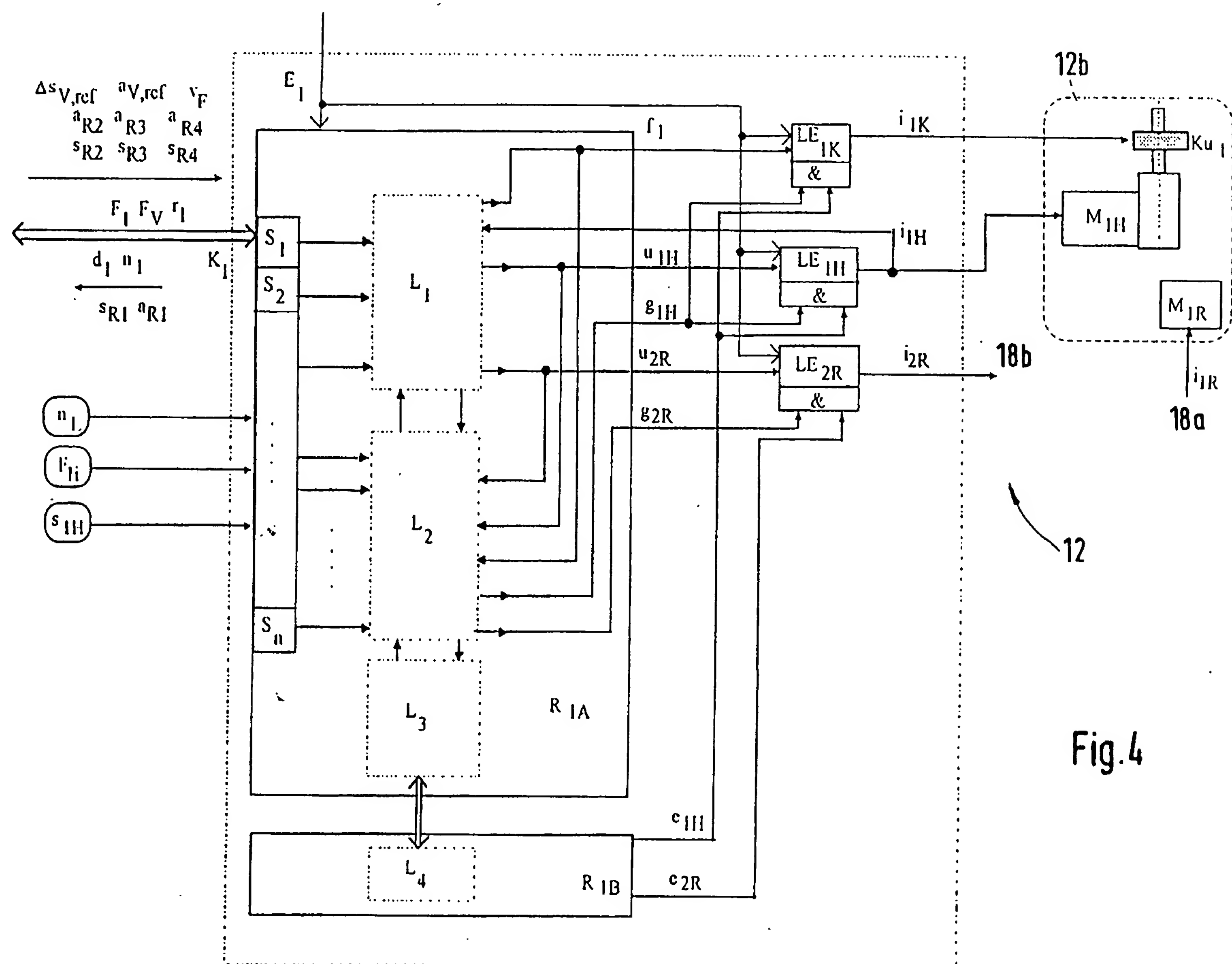


Fig.3



12b
Ku 1
M 1H
M 1R
i 1R
18a
18b
12
E 1
f 1
i 1K
LE 1K
&
i 1H
u 1H
LE 1H
&
g 1H
u 2R
LE 2R
&
i 2R
g 2R
c 1H
c 2R
L 1
L 2
L 3
L 4
R 1A
R 1B
S 1
S 2
S n
K 1
Δs V,ref a V,ref v F
a R2 a R3 a R4
s R2 s R3 s R4
F 1 F V r 1
d 1 n 1
s R1 a R1
n L
r 1i
s 1H

Fig. 4

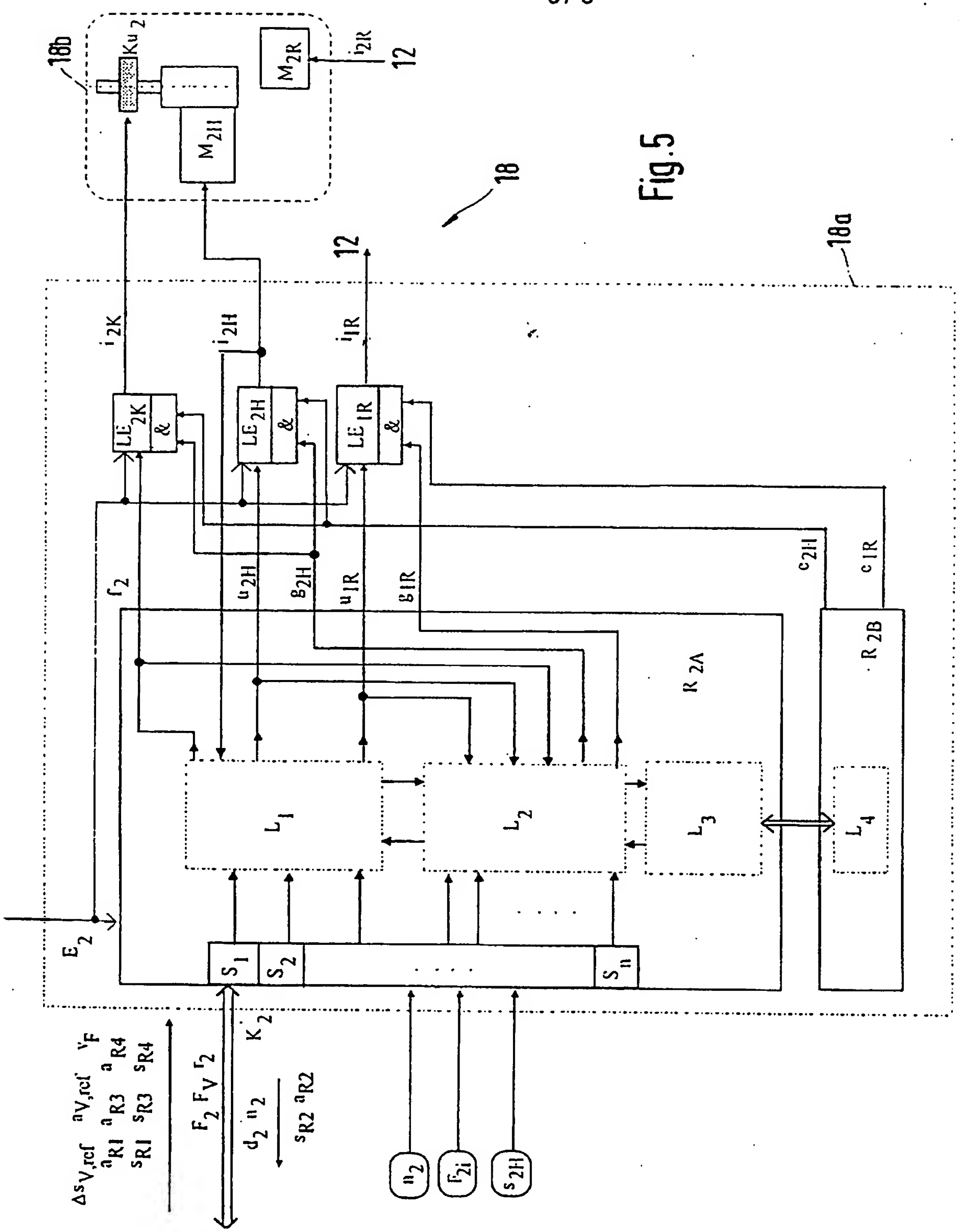

18
18a
18b
12
E2
L1
L2
L3
L4
R2A
R2B
S1
S2
Sn
LE2K
LE2H
LE1R
M2H
M2R
Ku2
i2K
i2H
i1R
i2R
c2H
c1R
u2H
g2H
u1R
g1R
r2
K2
n2
F2i
s2H

Fig.5

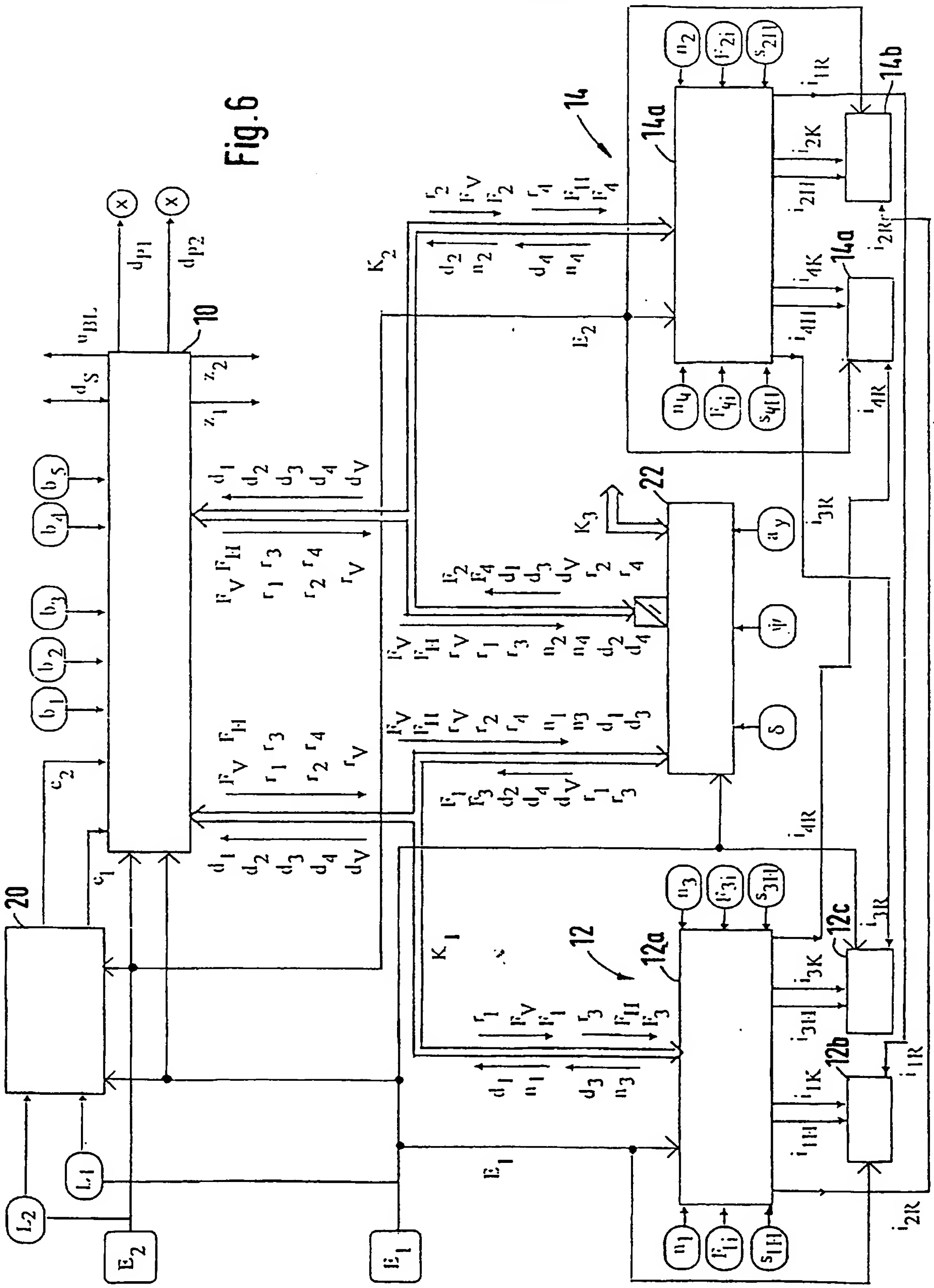


Fig.6

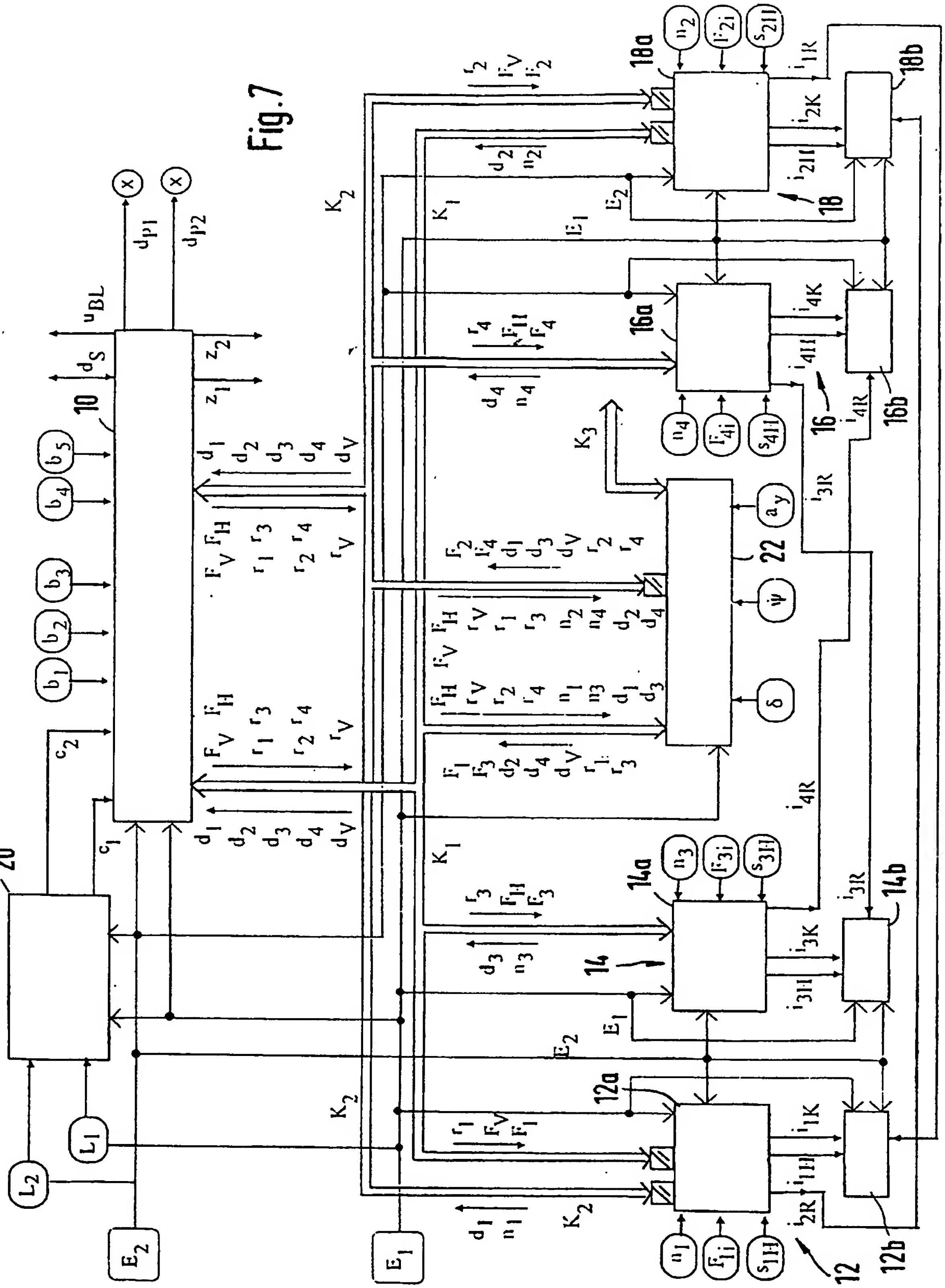
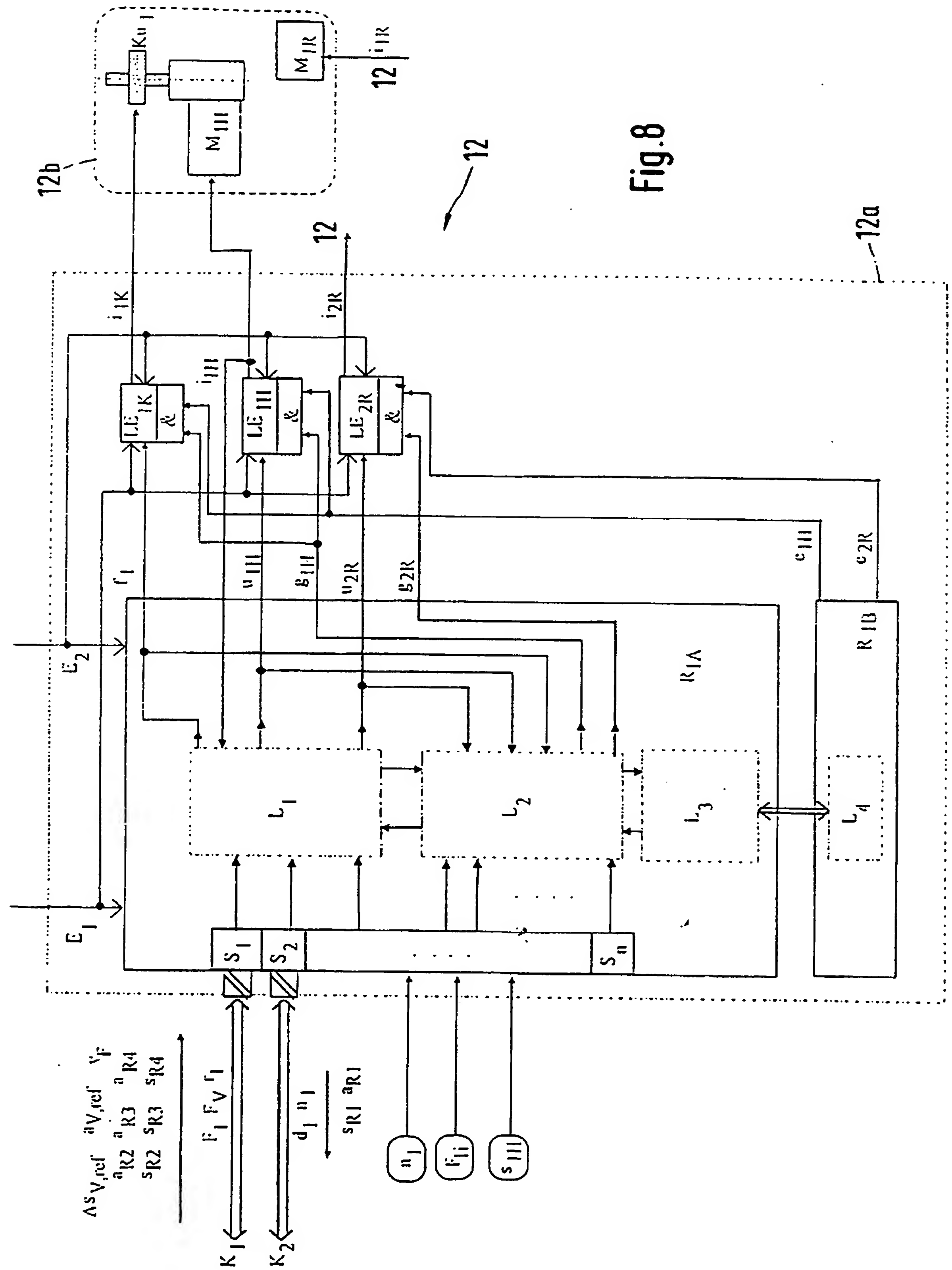


Fig.7



12b
M1R
i1R
12
MIII
12
12
12a
i1K
iIII
i2R
LE1K
LEIII
LE2R
&
r1
uIII
gIII
u2R
g2R
cIII
c2R
E2
E1
R1A
R1B
L1
L2
L3
L4
S1
S2
Sn
K1
K2
n1
F1i
sIII

Fig.8

Electromechanical braking system for a motor vehicle

Prior art

What is described is a decentralized braking ("brake by wire") system for a motor vehicle, which system meets, in particular, the high technical requirements in respect of safety and availability because of its decentralized design.

A braking system of this kind is known, for example, from DE-A 196 34 567. The braking system indicated in the latter has a decentralized structure in which a pedal unit for forming the guide quantities which are dependent upon the driver's wishes, and, if necessary, a processing unit for taking additional functions into account, and also wheel-pair units for controlling or regulating the adjusting members of the wheel brakes, are connected via one or more communication systems. Furthermore, the braking system is supplied with power from at least two on-board supply networks. This guarantees satisfactory safety and availability of the braking system. More detailed observations concerning the brake-adjuster and the taking into account of characteristics of the said adjuster in the regulation of the system and/or in connection with its safety and availability are not described in the said specification.

The object of the invention is therefore to indicate measures for taking into account characteristics of a brake-adjuster, which comprises a parking brake function and/or additional resetting facilities, in the regulation of the system and/or in connection with its safety and availability.

This is achieved by means of the characterising features of the independent patent claims.

Advantages of the invention

The operating properties of the braking system are considerably improved by the interplay of electric motor and parking brake (for example of an electromagnetic disengaging device) for the purpose of producing a movement displacing the brake linings of a disc or drum brake.

What is particularly advantageous is that, as a result of this interplay, the braking moment can be built up and maintained with little expenditure of energy. Under these circumstances, the use of a disengaging device is advantageous, because a braking force which has been introduced can be maintained in a lasting manner without the expenditure of energy. A parking brake function can be easily achieved as a result of this.

By means of an additional resetting facility it is possible to achieve releasing of the brake, even in the case of failure of the power supply which is triggered from a control unit supplied by another supply system.

Drawings:

The invention will be explained in greater detail below with the aid of the forms of embodiment represented in the drawings. Figure 1 shows a first exemplified embodiment of the structure of an electromechanical braking system. Figure 2 portrays the structure of the pedal unit, figure 3 that of the processing unit, and figures 4 and 5 the structures of wheel units belonging to the said braking system. Figures 6 and 7 show the structures of a second and third exemplified embodiment of an electromechanical braking system, while the structure of a wheel unit belonging to the third exemplified embodiment is represented in figure 8.

Description of exemplified embodiments

What is envisaged is the control or regulation of the service brake and parking brake functions of the braking installation of a motor vehicle. Through the decentralized distribution of the braking system and the redundancies provided for in the system, braking functionality is maintained in a high measure if static and dynamic faults occur, and the operating reliability of the braking installation is ensured. In addition, fault conditions are stored for servicing purposes and, if necessary, signalled. In this connection, the abbreviated designations introduced in the text and figures for components and signals are summarised in the appendix.

Figure 1 shows a first exemplified embodiment for the structure of an electronic braking system and the signals exchanged in each case. The system is characterised by a decentralized structure which ensues from the following system components: pedal unit 10, four wheel units 12, 14, 16 and 18, power diagnostic unit 20 and processing unit 22.

The pedal module 10 of the electromechanical braking system handles, primarily, detection of the driver's wish for braking, analysis of the overall condition of the system and the initiation of fall-back strategies in the event of a fault.

Each wheel unit (12, 14, 16, 18) is made up of a wheel module (12a, 14a, 16a, 18a), the wheel sensor system (cf., for example, n1, F1i, s1H, etc.) and an actuator (12b, 14b, 16b, 18b). A wheel module (12a, 14a, 16a, 18a) comprises, in each case, a microcomputer system, a monitoring component and the power electronics for triggering the actuator.

The supplying of the electrical system with electrical power takes place via the two independent on-board supply networks E_1 and E_2. Two wheel units at a time are supplied from the same power source. In the system structure considered in figure 1, the starting point is a diagonal distribution, that is to say the wheel units (12, 14) for the left front and rear right wheels are fed by a common power source E_1. The same applies to the wheel units (16, 18) for the front right and rear left wheels, which are supplied from the power source E_2. A design variant in which the two wheel units on one axle are each associated with a power source is likewise possible, but no further consideration will be given to this in what follows. In that distribution, the modes of procedure described below are likewise used with the corresponding advantages. The wheel units are disposed in the vicinity of the particular wheel brake, while the pedal unit and processing unit are mounted, either together or separately, at a central point.

The exchange of data between the individual components of the braking system occurs by means of two independent communication arrangements K_1 and K_2, which are preferably realised as serial bus systems, for example CAN's. The communication arrangements K_1 and K_2 are fed by the various on-board supply networks. In addition, connection to the control unit of the engine management system is realised by means of a communication system K_3.

Triggering of the appertaining actuator for stabilizing the desired clamping force or the desired braking moment is realised in each wheel module. For this purpose, the wheel clamping force or wheel braking moment is detected by sensors in each actuator alternately. The electromechanical actuator acts, via a gear unit stage, on the clamping paths of disc or drum brakes without a hydraulic intermediate stage.

For this purpose, the wheel unit regulates the clamping force or braking moment specific to the individual wheel. The necessary guide quantity is predetermined via the associated bus system.

In a preferred exemplified embodiment, the actuator (12b, 14b, 16b, 18b) of a wheel unit additionally contains an electromagnetically ventilated disengaging device (triggering via i1K, i2K, i3K, i4K) which, on the one hand, exercises the parking brake function and in addition, in stationary braking phases, locks the braking system in the current position without consuming power. In addition, there is integrated into the actuator (12b, 14b, 16b, 18b) of any one wheel, a resetting arrangement (triggering via i1R, i2R, i3R, i4R) which, in the case of all types of faults which would prevent release of the brakes of a wheel, clears the affected wheel. In order to be able to master these types of faults, even in the case of failure of a power diagnostic unit (20), the resetting arrangement is triggered by the adjacent wheel unit on the same axle (for example, from 18a for 12b). In the case of the diagonal distribution of the power circuits which is under consideration, the two wheel units on one axis are always fed from different power sources. As a result of this it is possible, in the case of failure of one power source, to achieve at least triggering of the affected actuator by means of the resetting arrangement in any condition whatsoever.

The power diagnostic module (20) ascertains the state of charge of the power supply units and delivers this information (c_1, c_2) to the pedal module (10).

A more detailed description of the functions and structure of the system components of the electromechanical braking system will be given in the following sections with the aid of figures 2 to 5.

Figure 2 shows the composition of the pedal module (10) in principle.

The tasks of these system components are the detection of the driver's wish for braking, namely in respect of the service brake and parking brake, and the formation of the guide quantities necessary for this purpose for the wheels on the front and rear axles; the detection and evaluation of the status messages of all the system components of the electromechanical braking system; the analysis of the current overall condition of the braking system and, if necessary, the initiation of fall-back measures and the signalling of the fault condition to the driver or else storage within a fault memory; the initializing of all the components of the braking system after the ignition is switched on or when the brake is actuated with the ignition switched off; the switching-off of the braking system after a journey has been completed; and the triggering of the brake light.

Detection of the driver's wish for a service braking operation is effected by the independent sensors b_1, b_2 and b_3 which, preferably in a diversitary realisation, detect the driver's wish in analog form (brake pedal angle and/or the force of actuation) at the brake pedal. The sensors are fed by the different power supplies E_1 or E_2, e.g. the sensors b_1 and b_2 by the power supply E_1 and the sensors b_2 and b_3 by the power supply E_2. The driver's wish for actuation of the parking brake is detected via the sensors b_4 and b_5 (likewise, for example, by detecting the deflection of the parking brake lever), which are fed by the various power supplies. One analog sensor each for detecting the wish for service braking and the wish for parking braking could also be replaced by a binary transmitter.

The pedal module 10 itself is designed so as to be fault-tolerant, for example by realisation by means of a redundant microcomputer system, which consists of the microcomputers P_1 and P_2 and, in addition, contains the necessary peripheral, memory and watchdog assemblies, and also by means of a monitoring component p_3. The microcomputers p_1 and p_2 and also the monitoring component p_3 communicate via the internal communication channel C which is realised, for example, by a serial bus system or with the aid of serial interfaces. Within the microcomputer systems p_1 and p_2, the independent programs Pr1 and Pr2 are implemented. By means of the computer program Pr1 and via the input interface U_1, the sensor signals b_1 to b_5 are detected, stored and made available to the microcomputer P_2 via the communication channel C. In a corresponding manner, the sensor signals b_1 to b_5 are detected, stored and transmitted to the microcomputer P_1 by means of the computer program Pr2 and via the input interface U_2. 6 measured values of the driver's wish for service braking and 4 measured values of the driver's wish for actuation of the parking brake are therefore available within the two computers.

A representative signal value for the wish for service braking $b_{B,\,rep}$ is ascertained in the microcomputers P_1 and P_2, in each case, from the measured values for the service braking operation, by majority selection in each case. This takes place with weighting of possible individual faults, through the fact that those individual measured values which differ from the others beyond a certain measure are not drawn upon for forming the reference values. The reference values calculated in the microcomputers P_1 and P_2 are designated by $b_{B,rep,1}$ and $b_{B,rep,2}$ respectively . If the reference value $b_{B,rep,1}$ exceeds a predeterminable limit value, the brake light is triggered by means of the signal u_{BL}.

Representative signal values are likewise calculated in the two microcomputers from the measured values of the driver's wish for actuation of the parking brake. The representative signal values ascertained in the microcomputers P_1 and P_2 are designated by $b_{F,rep,1}$ and $b_{F,rep,2}$. These representative signal values are the maximum values of the measured sensor signals b_4 and b_5 when the motor car is at a standstill (as is ascertained, for example, by evaluating one or more wheel speed signals), and the minimum values of the said two sensor signals when the motor car is in the moving state (that is to say is other than at a standstill).

The guide quantity for the desired mean clamping force or desired mean braking moment of a wheel in the course of a service braking operation is calculated from the reference values $b_{B,rep,1}$ and $b_{B,rep,2}$ in the two microcomputers by means of a stored pedal characteristic in each case. This guide quantity is designated by $F_{B,res,1}$ in the microcomputer P_1 and by $F_{B,res,2}$ in the microcomputer P_2.

The driver's wish for the mean clamping force or the mean braking moment of a wheel in a parking braking operation is likewise ascertained from the sensor signals $b_{F,rep,1}$ and $b_{F,rep,2}$ in the microcomputers P_1 and P_2, in each case using a predeterminable stored characteristic line. This guide quantity is designated by $F_{F,res,1}$ in the microcomputer P_1 and by $F_{F,res,2}$ in the microcomputer P_2.

The guide quantities calculated in a microcomputer for the wish for service braking and the wish for parking braking are made available to the other microcomputer in each case via the internal communication channel C. In the two microcomputers, $F_{B,res,1}$ is compared with $F_{B,res,2}$ and $F_{F,res,1}$ with $F_{F,res,2}$. If the compared values agree, in each case, within a predeterminable tolerance limit, a resulting quantity for the wish for service braking $F_{B,res}$ is formed by taking the

arithmetic mean of the quantities $F_{B,res,1}$ and $F_{B,res,2}$, and the resulting quantity for the wish for parking braking $F_{F,res}$ is formed by taking the arithmetic mean of the quantities $F_{F,res,1}$ and $F_{F,res,2}$.

If the compared values do not agree, the fault-free signal values both for the wish for service braking and also for the wish for parking braking are clearly detected by means of the monitoring component P_3 on the basis of the computer monitoring operation described below. In the two microcomputers, the fault-free signal values are assigned to the quantities $F_{B,res}$ and $F_{F,res}$ respectively.

The resulting mean clamping force of a wheel F_{res} arises from the signals $F_{B,res}$ and $F_{F,res}$ as a result of the relation F_{res} = maximum ($F_{B,res}$, $F_{F,res}$). In an alternative embodiment, F_{res} might also correspond to the resulting mean braking moment of a wheel which is required by actuation of the service or parking brake. The desired clamping forces or braking moments for the wheels of the front axle F_V or for the wheels of the rear axle F_H are calculated from F_{res} for the purposes of suitable distribution.

By means of the communication systems K_1 and K_2, the pedal module transmits the desired values for the clamping forces or braking moments F_V and F_H to the connected components of the electromechanical braking system.

As a result of the diversitary detection and calculation, faults which would lead to unintended braking or to an incorrect guide quantity for the wheel clamping force or wheel braking moment, are identified. Adulterated memory contents, which would lead to an identical fault effect, are also identified. The monitoring component P_3 communicates with the microcomputers P_1 and P_2 respectively by means of the internal bus system C. It serves to monitor the program flows in the programs Pr1 and Pr2 and,

in addition, to check the computing capacity of the microcomputers P_1 and P_2. In order to guarantee safety in the event of a computer fault in P_1 or P_2, the programs Pr1 and Pr2 must nevertheless still run correctly in this event of a fault, or else the incorrect running must be reliably identified. In the case of incorrect running, the appertaining computer channel is switched off and fault signalling occurs via the signals d_{p1} and d_{p2} respectively. In the variant of embodiment represented, verification of operability takes place by a question/answer communication. The microcomputers P_1 and P_2 collect a question from the monitoring component and answer it, in each case taking into account all the parts of the program that are relevant to safety, within a predetermined time interval. The questions are to be predetermined in such a way that a correct answer is given only if there is fault-free running of these parts of the program, particularly of the computer functioning test (RAM test, ROM test, etc.) and of the command test (as regards addition, subtraction, etc.). The partial answers formed from the partial programs are combined in each microcomputer to form an overall answer. In the monitoring component, the overall answers supplied by the microcomputers P_1 and P_2 in each case are checked in respect of the time interval of arrival and for agreement, with accuracy to the last bit, with the correct answer matching the question, and fault-mastering strategies, for example signalling and the switching-off of a channel, are initiated if necessary. The operability of the monitoring component is checked by the microcomputers P_1 and P_2 by means of suitable test questions. These test questions can be correctly answered by the monitoring component only if the functioning is completely correct.

In the pedal module, the internal fault conditions and fault signal messages d_1, d_2, d_3 and d_4 from the wheel units connected, and the fault message d_v from the processing unit are also detected and stored in a fault memory. The status

signals c_1 and c_2 from the power diagnostic unit are also detected. This detection occurs both during a test phase before the start of a journey and also in all the operational phases of a journey. All the fault and status signals are evaluated within the pedal module by means of predetermined tables in which there is deposited, for each type of fault and for each status, an action which is to be performed. As a result of the evaluation, there are initiated in the journey phase, in a manner corresponding to the endangering potential of the fault conditions, messages for fall-back strategies in the various components of the braking system, which messages are transmitted to the processing unit and the wheel units by means of the signals r_1, r_2, r_3, r_4 and r_v. In the case of faults which are relevant to safety, these are signalled to the driver by means of the fault signals d_{P1} or d_{P2}. In the case of fault conditions which are detected in the test phase before the start of a journey, these are likewise signalled to the driver. In the case of fault conditions which are critical to safety, initializing of the braking system is discontinued and the releasing of the parking brake is prevented. In the case of operating conditions critical to safety that occur during a journey, intervention in the engine management system is also possible in order to reduce the driving moment available.

By means of the signal lines z_1 and z_2 respectively, the other components of the electromechanical braking system are initialized by the pedal module after the switching-on of the ignition or even when the brake is actuated with the ignition switched off. Selective switching-off of the system components also takes place by means of these signals when the journey has been completed.

The servicing interface d_S enables the servicing personnel to have access to the braking system and to read out the fault memory for the entire system.

The power diagnostic unit (20) handles the monitoring of the power supply units (batteries) with regard to adequate capacity for the output and power required in braking operations. For this purpose, it is necessary to ensure at least the power needed for achieving the minimum braking action prescribed by the legislature. Monitoring takes place by means of suitable sensors L_1 and L_2, for example for measuring the charging and feeder currents, and by means of a mathematical model. This model takes into account the electrochemical and physical properties, and also the antecedents, for example the number of total discharges, of the power supply units. The power diagnostic unit is preferably realised in the form of a redundant microcomputer system which is fed via both power sources and the partial systems of which are able to exchange data via an internal bus system.

The primary functions of the braking system are carried out in the processing unit (22). These include, in particular, the calculations of the guide quantities F_1, F_2, F_3 and F_4 specific to the individual wheels for the clamping forces or braking moments of a wheel. The calculations take place incorporating known principles such as the taking into account of the rotational speeds specific to the wheels in full braking operations for the purposes of anti-locking protection, the taking into account of a drive-slip regulating function, the implementation of travel-dynamics control in order to avoid skid conditions, with the incorporation of other sensors, for example for steering wheel angle δ_L, transverse acceleration a_y and yaw angle velocity $\dot{\Psi}$, the taking into account of the brake lining thickness specific to the individual wheels in partial braking operations with the aim of achieving uniform wearing of the brake linings, the implementation of a hill-holder function, the taking into account of the load condition in order to achieve optimum distribution of braking force to the wheels of the front and rear axles,

the achieving of an adaptive braking force distribution between that wheel of an axle which is on the inside of a bend and the wheel which is on the outside of a bend in dependence upon the measured steering angle in order to achieve improved travel dynamics, corrections to the individual braking forces in the case of failure of a wheel unit, selective interventions in the engine management system in the case of a wish for braking via the communication system K_3, and intervention in the engine management system in the event of a fault in the braking system which is critical to safety. In addition, the processing unit also has available the measured actual values of the regulating quantities F1i, F2i, F3i and F4i for calculating the guide quantities F1 to F4 specific to the individual wheels. Optionally, it is also possible for the determination of travel-dynamic reference quantities for supporting the monitoring functions to be ascertained within the wheel units. Details will be explained when describing the functions of the wheel unit.

According to figure 3, the processing unit (22) is made up, in a redundant manner, of two microcomputer systems RV1 and RV2 which exchange the calculated data via an internal communication channel C1. Via the two communication systems K_1 and K_2, the processing unit (22) receives, from the wheel units (12 to 18), the rotational speeds (n1 to n4) specific to the individual wheels, the actual values of the clamping force or braking moment (F1i to F4i) and, from the pedal unit (10), the guide quantities for the clamping force or braking moment for the wheels of the front axle F_V or for the wheels of the rear axle F_H.

In the case of failure of a computer channel in the pedal unit (10), the transport of data via the connected communication system is interrupted. In this fault situation, the processing unit (22) conveys the guide quantities F_V and F_H, which are received by the other

computer channel of the pedal module (10) and are specific to the individual axles, and also messages (r1 to r4) for the fall-back strategies, to the connected wheel units (12 to 18). Moreover, in the case of this fault, the diagnostic messages (d1 to d4) of the wheel units can be passed on to the operative computer channel of the pedal module. For this purpose, failure of the microprocessor P_2 in the pedal module will be considered as an example. In this event of a fault, the messages can be conveyed by the pedal module, via the communication system K_1 and the processing unit, to the wheel modules 2 and 4. The diagnostic messages from the wheel modules 2 and 4 take the reverse route. For calculating those guide quantities specific to individual wheels which are required for a travel-dynamics control function, the quantities necessary for this purpose (steering angle, transverse acceleration and rate of rotation) are additionally detected in the processing unit (22).

The abovementioned calculations are carried out independently in the two computer systems RV1 and RV2, and compared with one another. If the results are inconsistent, the processing unit is switched off and a fault status message d_V is dispatched via the communication system.

Operations regulating the clamping forces or braking moments specific to individual wheels are realised within the wheel units. The communications systems K_1 and K_2 supply the guide quantities for this purpose.

The wheel units are fed by different electrical power sources, the wheel units 12 and 14 from power source E_1, and the wheel units 16 and 18 from power source E_2. In addition, connection of the wheel units to the other system modules is realised with the aid of different communication

systems. Wheel units 12 and 14 communicate via K_1, and wheel units 16 and 18 via K_2.

Consideration will be given below to the wheel unit 12 according to figure 4. The other wheel units are made up in a corresponding manner. The wheel unit 12 serves for regulating the clamping force or braking moment of a wheel, and for initiating a retraction strategy in the case of a breakdown in the actuator 18b of the wheel unit 18. The wheel unit 12 communicates with the other system components by means of the communication system K_1. Via the said system, the wheel unit receives the following quantities:

F_1: Guide quantity specific to the individual wheel for regulating the clamping force or braking moment of the wheel. This quantity is supplied at the same point in time as an intervention by the processing unit (22) for anti-locking protection, anti-slip regulation or travel-dynamics control purposes. In another variant of embodiment, this guide quantity might additionally be calculated by the processing unit specifically for the following tasks:

a) for achieving uniform wearing of all the brake linings of a vehicle

b) for adapting the distribution of the driver's overall wish for braking moment to the wheels of the front or rear axle in dependence upon the momentary axle load distribution

c) for achieving an adaptive braking force distribution between that wheel of an axle which is on the inside of a bend and the wheel on the outside of the bend, in dependence upon the steering angle measured, in order to achieve improved travel dynamics.

F_v: Substitute front axle guide quantity for the clamping force or braking moment of a wheel on the front axle. (The substitute guide quantity F_H is used in a

corresponding manner for the wheel units associated with the rear axle.) The guide quantity F_v is formed from the driver's wish for service braking and parking braking and supplied to the two wheel units on the front axle and also to the processing unit. The guide quantity specific to the axle is used within a wheel unit for regulating the clamping force or braking moment, provided no differing guide quantity specific to the individual wheel has been formed in the processing unit, or else in the case of failure of the processing unit.

r_1: Control message for initiating a modified processing flow in the wheel unit. This message is formed by the pedal unit or the processing unit from the fault signal messages arriving from the system modules connected.

The signals arriving via the communication system are deposited, in a redundant manner, in the memory cells S_i of the microcomputer system R_{1A}. In variants of embodiment, the following other signals arriving via the communication system K_1 may additionally be processed for monitoring the functioning of the wheel unit:

a_{R2}, a_{R3}, a_{R4},:	Decelerations of the other wheels
$a_{v,\ ref}$:	Reference value for the deceleration difference between the wheels on the front axle
s_{R2}, s_{R3}, s_{R4},:	Slip of the other wheels
$\Delta s_{v,ref}$:	Reference value for the slip difference between the wheels on the front axle
v_F:	Estimated value for vehicle speed

As the output quantities of the wheel unit, the following signals are fed into the connected system modules via the communication system K_1:

n_1: Edited rotational speed signal of the associated wheel

d_1: Cyclical fault signal message of the wheel unit

Fli Measured actual value of the regulating quantity

In variants of embodiment, the following other quantities are additionally needed by the wheel unit 12 for monitoring functioning in the other wheel units:

a_{R1}: deceleration of the associated wheel

s_{R1}: slip of the associated wheel

These signals are supplied to the other system modules via the communication system K_1.

The wheel unit 12 comprises the following components:

a) Microcomputer system R_{1A} with the appertaining peripheral, memory and watchdog assemblies

b) Monitoring component R_{1B}

c) Electric motor M_{1H} including the required gear unit stage for converting the rotational movement into a movement advancing the brake lining of a disc or drum brake

d) Electromagnetically ventilated disengaging device Ku_1 which engages with a shaft lying within the moment flux between the electric motor and the brake lining and which, in the current-less condition, is closed by means of a spring element and, in this condition, ensures that the current angular position of the shaft is maintained. The design of this disengaging device must ensure that any clamping force inserted can thereby be adhered to on the brake disc.

e) Resetting module M_{1R} realised in the form of an electromagnetically actuatable disengaging device or

as an electric motor. This module is fed by the power source E_2 and triggered by the wheel unit 18.

f) Power electronics LE_{1H} for triggering the electric motor M_{1H}

g) Power electronics LE_{1K} for triggering the electromagnetically actuated disengaging device Ku_1

h) Power electronics LE_{2R} for triggering the resetting module M_{2R} which is integrated into the wheel unit 18.

Items c), d) and e) will be designated below as the actuator 12b of the wheel unit 12.

The following input signals originating from the associated wheel are fed into the microcomputer system R_{1A} via peripheral input assemblies and deposited in a redundant manner in the memory cells S_1: the rotational speed n_1 of the wheel, the actual value for the wheel clamping force or wheel braking moment F_{1i}, the clamping path or angle of rotation of the gear unit stage or of the electric motor S_{1H} and, if necessary, the motor current of the actuator i_{1H}.

Within the microcomputer R_{1A}, the guide quantity F_{1F} is first of all selected from the quantities F_1 or F_V received cyclically via the communication channel. By means of the actual value F_{1i} currently measured for the wheel clamping force or wheel braking moment, the regulating difference x_{d1} is formed therefrom in accordance with

$$x_{d1}(t) = F_{1F}(t) - F_{1i}(t) \quad (1)$$

With limit values ϵ and μ, which are to be predetermined, and time intervals T_ϵ and T_μ, the comparisons can then be carried out in accordance with

$$| x_{d1}(t) | \le \epsilon \qquad \text{for } 0 < t < T_\epsilon \quad (2)$$

$$| x_{d1}(t) / dt | \le \mu \qquad \text{for } 0 < t < T_\mu \quad (3)$$

If the conditions (2) and (3) are fulfilled, no adjusting interventions of any kind are carried out at the actuator. If this condition is not fulfilled, the required, current adjusting quantity for stabilizing the wheel clamping force or wheel braking moment is calculated by means of a digital regulating algorithm, taking into account the last adjusting quantity outputted (for example from a proportional/integral regulator or from a proportional/integral/differential regulator). This adjusting quantity is outputted to the power electronics LE_{1H} in the form of the PWM signal u_{1H}. In addition, the electromagnetically ventilated disengaging device Ku_1 is triggered via the control signal f_1 and the power electronics LE_{1K}, as a result of which a rotational movement of the motor for achieving a modified wheel clamping force is made possible for the first time. If the conditions (2) and (3) are fulfilled during the stabilizing of the clamping force or wheel braking moment, triggering of the electromagnetically actuated disengaging device Ku_1 is terminated and the electric motor M_{1H} is then switched so as to be devoid of current. In order to avoid an unwanted modification of the wheel clamping force because of a malfunction of the microcomputer system R_{1A}, triggering of the electric motor by means of the current i_{1H} is made possible only if the clearing signal g_{1H} and, in addition, the clearing signal e_{1H} from the monitoring component R_{1B} are lining up at the triggering part of the power electronics LE_{1H} (cf. & linkage in LE_{1H}).

In order to also be able to avoid an unwanted diminution in the wheel clamping force maintained by the disengaging device, triggering of the disengaging device Ku_1 by means of the current i_{1K} is possible only if both the clearing signal g_{1H} and the clearing signal e_{1H} are supplied by the monitoring component R_{1B} (cf & linkage in LE_{1K}). As a result of the inclusion of the electromagnetic disengaging device in the regulating operation it is possible, in the case of

an approximately stationary braking wish on the part of the driver, for the required clamping force to be initially applied via the electric motor and then maintained, without the consumption of electrical power, solely by the spring forces within the electromagnetically actuated disengaging device. By this means, the clamping forces required when the parking brake of a motor vehicle is actuated can easily be initiated and also retained without power. For releasing the brake on a wheel, the disengaging device is first of all opened by means of the triggering signal f_1, and then the electric motor M_{1H} is triggered with negative voltage. If this release is prevented by a fault in the actuating system, for example as a result of sticking of the gear unit stage in the said actuating system, this fault can be clearly identified with the aid of the measured wheel clamping force or wheel braking moment. This takes place, for example, by comparing the triggering and the rotational speed of the wheel and, if necessary, the angle of rotation. Jamming is identified if, for example, in spite of actuation, no change in the angle of rotation of the electric motor is identified and/or, in the case of non-triggering, braking slip of the associated wheel is present. Regulation is thereupon discontinued and a fault message d_1 is dispatched via the communication system. This message is evaluated in the pedal unit (10) and, as a result of this, a fault-eliminating measure is initiated. By means of a fall-back message r_2, which is sent via the communication system K_2, the wheel unit 18 represented in figure 5 receives the information to trigger the resetting arrangement M_{1R} in the actuating system 12b via the power electronics LE_{1R} and the signal i_{1R}. Since the resetting arrangement M_{1R} is triggered by means of the power source E_2, releasing of the braking function of the wheel associated with the wheel unit 12 can be carried out, even in the case of failure of the power source E_1.

In the wheel unit 12, there is a corresponding reaction to a fall-back message r_1 which contains the information for releasing the wheel which has been braked as a result of a fault situation and is associated with the wheel unit 18. This type of message leads to the outputting of the signal U_{2R}, with which the power electronics LE_{2R} are activated. The control signal i_{2R} for addressing the resetting arrangement in the actuator 18b is, however, only activated if the clearing signals g_{2R} and e_{2R} are available (cf. & linkage in LE_{2R}).

The correctness of the measured actual value of the wheel clamping force or wheel braking moment can be ensured by an analytical redundancy. If this redundancy is realised in accordance with the invention, one or more of the following measures can be carried out:

Comparison of the actual values of the wheel clamping force or wheel braking moment with a reference quantity $F_{r,a}$. For determining $F_{r,a}$, the change in the position-measuring quantity or rotational angle-measuring quantity s_{1H} is first of all measured from the point in time at which the braking operation starts, and is then converted to the physical dimension of a force or moment by means of a design-determined function. This function takes into account all the elasticities of the components disposed in the power flow of the actuator. In the event of regulation of the wheel braking moment, another temperature-dependent friction model of the brake disc (for example a modelling of the warming-up and cooling-down of the disc) is additionally implemented in the function.

Comparison of the actual value of the wheel clamping force or wheel braking moment with a reference quantity $F_{r,b}$. For determining $F_{r,b}$, the current of the electric motor M_{1H} is measured during a stationary braking phase and is then converted to the physical dimension of a force or moment by

means of a function which has been determined beforehand. This function takes into account, first of all, the design data of the electric motor and of the gear unit, if necessary with the incorporation of a temperature and friction model. In addition, the current effective input voltage is taken into account, and so too is the direction of rotation before the stationary working point is reached. In the event of regulation of the wheel braking moment, another temperature-dependent friction model of the brake disc can additionally be implemented in the function.

Another method is based on comparative observation of the deceleration of the wheels in the partial braking range. Calculation of the wheel decelerations in the individual wheel units is started by means of a message from the processing unit at the point in time T_x. Calculation of the deceleration of the wheel associated with the wheel unit 12 takes place in accordance with the equation

$$a_{R1}(T_x) = C_1 \; [\; n(T_x) - n(T_x - T_a) \;] \tag{4}$$

In the latter, T_a is the cyclical scanning time at which the detection of rotational speed is carried out at each wheel unit, and C_1 is a constant which is fixed by the wheel geometry and the scanning time.

From the deceleration values of the wheels on the front axle $a_{R1}(T_x)$ and $a_{R2}(T_x)$, the deceleration difference $\Delta a_v(T_x)$ of the front axle wheels is formed:

$$\Delta a_v(T_x) = a_{R1}(T_x) - a_{R2}(T_x) \tag{5}$$

The value $a_{R2}(T_x)$ required for this purpose is fed in by the wheel unit 18 via the communication system K_1. For the deceleration difference $\Delta a_v(T_x)$, the following must apply, with correct functioning of the clamping force or braking moment regulating system:

$$\left| \Delta a_v(T_x) - \Delta a_{v,ref}(T_x) \right| < \epsilon_a \qquad (6)$$

In the latter, $\Delta a_{v,ref}$ is a reference value for the deceleration difference between the wheels on the front axle. ϵ_a describes a parameterizable fault limit value. The reference value $\Delta a_{v,ref}$ is calculated in the processing unit by means of a mathematical model, using the cyclically detected travel-dynamic reference quantities: steering wheel angle δ_L, transverse acceleration a_y and yaw angle velocity $\dot{\Psi}$, and also taking into account an estimated value for the vehicle speed v_F. If the condition (6) is violated, a fault in the clamping force or braking moment sensor of one of the wheels can be inferred therefrom. Through the use of both wheels on an axle for identifying faults, disturbance quantity influences which act upon both wheels are eliminated. In this process, the assumption proceeded upon is that the functionality of the regulating algorithm and of the adjusting quantity output, and also the fault-free detection of the rotational speeds at both wheels on the front axle, are ensured by other monitoring methods. The assigning of an identified fault to wheel unit 12 or wheel unit 18 takes place by incorporation of the two wheel deceleration values for the rear axle $a_{R3}(T_x)$ and $a_{R4}(T_x)$ (for example, by comparison of the individual quantity with the corresponding quantity from a rear wheel).

Another method is based on comparative observation of the slip values of the individual wheels in the partial braking range. Calculation of the slip in the individual wheel units is started by means of a message from the processing unit at the point in time T_x. Within the wheel unit 12, the slip of the associated wheel is calculated with the aid of the rotational speed n_1 of the wheel and the estimated value for the vehicle speed v_F in accordance with the equation

$$s_{R1}(T_x) = 1 - C_2\ n_1(T_x)/v_F(T_x) \qquad (7)$$

The constant C_2 is determined by the wheel geometry. By means of the wheel slip $s_{R2}(T_x)$, which is fed in by the wheel unit 18 via the communication system, the difference in slip between the wheels on the front axle Δs_V can be calculated in accordance with

$$\Delta s_V(T_x) = s_{R1}(T_x) - s_{R2}(T_x) \quad (8)$$

For the difference in slip $\Delta s_V(T_x)$, the following must apply, with correct functioning of the clamping force or braking moment regulating system:

$$| \Delta s_V(T_x) - \Delta s_{V,ref}(T_x) | < \epsilon_s \quad (9)$$

In the latter, $\Delta s_{V,ref}$ is a reference value for the difference in slip between the wheels on the front axle. ϵ_s describes a parameterizable fault limit value. The reference value $\Delta s_{V,ref}$ is calculated in the processing unit by means of a mathematical model of the travel dynamics, using the cyclically detected measuring quantities: steering wheel angle δ_L, transverse acceleration a_y and yaw angle velocity $\dot{\Psi}$, and also taking into account the guide quantities specific to the individual wheel for the clamping forces or wheel braking moments:

$$\Delta s_{V,ref}(T_x) = f_1\{ \delta_L, a_y, \dot{\Psi}, F_1, F_2, F_3, F_4 \} \quad (10)$$

In another variant of embodiment, an improved reference quantity $\Delta s_{V,ref}$ can be ascertained, incorporating measured values or estimated values for the wheel loads F_{N1}, F_{N2}, F_{N3} and F_{N4}. For that purpose, $\Delta s_{V,ref}$ is formed in the processing unit via an expanded dynamic model. As a result of this, influences which are caused by displacement of wheel loads are taken into account in the calculation. If the condition (9) is violated, a fault in the clamping force sensor or braking moment sensor of one of the wheels can be inferred therefrom. In the process, the assumption

proceeded upon is that the functionality of the regulating functions and also the fault-free detection of the rotational speeds at both wheels on the front axle are ensured by other monitoring methods. The assigning of an identified fault to wheel unit 1 or wheel unit 2 takes place by incorporation of the two slip values for the wheels of the rear axle $s_{R3}(T_x)$ and $s_{R4}(T_x)$ (for example, by comparison of the individual quantity with the corresponding quantity for a rear wheel).

The monitoring concept of the wheel modules is structured with the aid of the four logic planes L_1, L_2, L_3 and L_4 and two hardware planes. The microcomputer system R_{1A} and the monitoring component R_{1B} operate in the hardware planes.

The monitoring component R_{1B} communicates with the microcomputer system R_{1A} by means of an internal bus system. It serves to check the computing capacity of the said microcomputer system and to monitor the program flows within the computer. The chosen type of data communication between the microcomputer system R_{1A} and the monitoring component R_{1B} permits mutual monitoring of the said components. To this end, the following tasks are assigned to the logic planes:

One plane 1 is realised in the microcomputer system R_{1A}. It handles the following tasks: calculation of the regulating function for triggering the electric motor M_{1H} ; triggering of the electromagnetically actuated disengaging device Ku_1; triggering of the resetting module M_{2R} ; calculations for checking the correctness of the measured actual value of the wheel clamping force or wheel braking moment F_{1i} by means of the analytical redundancy represented.

One plane 2 is likewise integrated into the microcomputer R_{1A}. This plane handles the testing of the correctness of the calculations carried out in plane 1 by means of

algorithms which are diversitary to those in plane 1. For carrying out the calculations, use is made, in addition, of the input data deposited in a redundant manner in the memory cells S_i, as a result of which faults can be identified by adulterated memory contents. The checking of the functioning of the regulator takes place by means of a mathematical model of the regulator which is connected in parallel and is calculated with the data, which are deposited in a redundant manner, for the alternative guide quantities F_1 or F_V and with the actual value of the wheel clamping force or wheel braking moment F_{1i}. If there are significant deviations between the model output quantity and the calculations carried out in plane 1, a fault condition is identified. In addition, correct functioning of the regulating section is also checked in plane 2. This purpose is served by a mathematical model of the regulating section which describes the dynamic correlation between the adjusting quantity and the regulating quantity F_{1i} even with the incorporation of disturbance quantities. The adjusting quantity calculated in the regulating algorithm in plane 1 is fed into this model. If there are significant deviations between the model output quantity and the actual value measured for the wheel clamping force or wheel braking moment F_{1i}, a fault condition is identified. The triggering signals f_1 for the electromagnetically ventilated disengaging device, and u_{2R} for the resetting module are likewise checked for correctness in plane 2 and, if necessary, fault conditions identified. The models used are derived from the physical correlations.

In the case of a fault which is identified in plane 3 and also in plane 2, the appertaining clearing signals g_{1H} and g_{2R} respectively are reset and a fault message d_1 is initiated via the communication system K_1.

The plane 3 is realised in the microcomputer R_{1A}. In order to guarantee safe functioning of the wheel unit in the

event of a computer or program fault, the programs in planes 1 and 2 must nevertheless still run correctly in the event of a fault, or else incorrect running must be reliably identified. In the variant of embodiment represented, verification takes place by question/answer communication between planes 3 and 4. The microcomputer system R_{1A} collects a question from the monitoring computer and answers it, in each case taking into account all the parts of the program that are relevant to safety, within a predetermined time interval. A question can be answered correctly only if there is fault-free running of the programs for the computer functioning test and the command test. The partial answers formed from the partial programs are combined to form an overall answer and fed to the plane 4 in the monitoring component.

This plane is realised in the monitoring component. In it, the overall answer supplied by the microcomputer R_{1A} is checked in respect of the time interval of arrival and for agreement, with accuracy to the last bit, with the correct answer matching the question. In the case of incorrect running of the question/answer communication with plane 3, the clearing signals e_{1H} and e_{2R} respectively are switched off in the monitoring component R_{1B}.

In another variant of embodiment (variant 2), the functions of two wheel units on a diagonal or on an axle are integrated into one wheel-pair unit in a manner corresponding to the previous embodiments. The structure of this variant of embodiment of the electromechanical braking system is represented in figure 6.

In variants 1 and 2 of the electromechanical braking system, in the case of a power supply or one of the communication systems K_1 or K_2 failing, there are always two wheels which are no longer ready for braking. This disadvantage is avoided in variant of embodiment 3. The

structure of this variant is represented in figure 7, and its wheel unit in figure 8. This variant differs from variant 1 which has been presented, in particular through the fact that:
the wheel modules of the front wheels are connected, by the redundant communication systems K_1 or K_2 in each case, to the other system modules, and that the wheel modules of the front wheels are fed with the aid of both power sources.

The functions described are realised by corresponding programs which run in the corresponding computers.

Appendix: List of terms

a_{R1}, a_{R2}, a_{R3}, a_{R4}:	Decelerations of the wheels
$a_{V,ref}$, $a_{H,ref}$:	Reference value for the difference in deceleration between the wheels on the front and rear axles respectively
a_y:	Transverse acceleration
b_1, b_2, b_3, :	Measured signals for the driver's wish (for example brake pedal angle)
b_4, b_5:	Measured signals for the wish for parking braking
$b_{B,rep,1}$, $b_{B,rep,2}$:	Reference values for the wish for service braking
$b_{F,rep,1}$, $b_{F,rep,2}$:	Reference values for the wish for parking braking
C:	Internal communication system
c_1, c_2:	Diagnostic signals of the state of charge of the power supply arrangements
d:	Triggering signal of a diagnostic unit
d_{P1}, d_{P2}:	Status messages about the condition of the electromechanical braking system
d_S:	Servicing interface in the pedal module
d_V:	Fault signals of the processing unit
d_1, d_2, d_3, d_4:	Fault messages of the wheel units
E_1, E_2:	Power supply
e_{1H}, e_{2H}, e_{3H}, e_{4H}:	Logical triggering signal for the power electronics of a wheel unit
e_{1R}, e_{2R}, e_{3R}, e_{4R}:	Logical triggering signal for the power electronics of the resetting arrangement of a wheel unit
$F_{B,res,1}$, $F_{B,res,2}$:	Guide quantity for the total force of the service brake
F_{res}:	Guide quantity for the wish for braking force
F_H:	Guide quantity for the clamping force (or wheel braking moment) for the wheels of the rear axle

F_F: Guide quantity for parking braking force

$F_{F,res,1}$, $F_{F,res,2}$: Guide quantity for the total force of the parking brake

F_H: Guide quantity for the clamping force (or wheel braking moment) for the wheels of the rear axle

F_1, F_2, F_3, F_4: Guide quantity specific to the individual wheel for wheel braking force or wheel braking moment

F_{1F}, F_{2F}, F_{3F}, F_{4F}: Selected guide quantity specific to the individual wheel for the wheel clamping force or wheel braking moment

F_{1i}, F_{2i}, F_{3i}, F_{4i}: Actual value for wheel braking force or wheel braking moment

f_1, f_2, f_3, f_4: Triggering signal for the electromagnetic clutch in a wheel unit

g_{1H}, g_{2H}, g_{3H}, g_{4H}: Logical triggering signal for the power electronics in a wheel unit

g_{1R}, g_{2R}, g_{3R}, g_{4R}: Logical triggering signal for the power electronics of the resetting arrangement in a wheel unit

i_{1K}, i_{2K}, i_{3K}, i_{4K}: Current for triggering an electromagnetic disengaging device in a wheel unit

i_{1H}, i_{2H}, i_{3H}, i_{4H}: Current for triggering the electric motor in a wheel unit

i_{1R}, i_{2R}, i_{3R}, i_{4R}: Current for triggering the resetting arrangement in a wheel unit

K_1, K_2, K_3: Communication arrangements

LE_{1H}, LE_{2H}, LE_{3H}, LE_{4H}: Power electronics for triggering the electric motor

LE_{1K}, LE_{2K}, LE_{3K}, LE_{4K}: Power electronics for triggering the electromagnetically actuated disengaging device

LE_{1R}, LE_{2R}, LE_{3R}, LE_{4R}: Power electronics for triggering the resetting arrangement

L_1, L_2:	Sensor system for determining the state of charge of an energy supply
n_1, n_2, n_3, n_4:	Measured values for wheel rotational speeds
P_1, P_2:	Microcomputers in the pedal module
P_3:	Monitoring components in the pedal module
r_1, r_2, r_3, r_4:	Control signals for initiating an altered processing flow in the wheel units
s_{H1}, s_{H2}, s_{H3}, s_{H4}:	Clamping path of the brake disc or brake drum or angle of rotation of the electric motor or of the gear unit stage
s_{R1}, s_{R2}, s_{R3}, s_{R4}:	Slip of the wheels
S_1 to S_n:	Memory cells in the wheel modules
U_1, U_2 :	Input interfaces of the pedal unit
u_{BL}:	Triggering signal for the brake light
u_{1H}, u_{2H}, u_{3H}, u_{4H}:	Triggering signal for the power electronics of the electric motor in the wheel unit
u_{1R}, u_{2R}, u_{3R}, u_{4R}:	Triggering signal for the power electronics of the resetting arrangement in the wheel unit
v_F:	Estimated value of the vehicle speed
x_{d1}, x_{d2}, x_{d3}, x_{d4}:	Regulating difference in a wheel unit
z_1, z_2:	Signal for initializing and switching off the components of the braking system
δ_L:	Steering angle
$\dot{\Psi}$:	Yaw angle velocity
$\Delta s_{V,ref}$, $\Delta s_{H,ref}$	Reference value for the difference in slip between the wheels on the front and rear axles respectively.

Claims

1. Electromechanical braking system for a motor vehicle, having at least one control unit (12a, 14a, 16a, 18a) which is associated with at least one wheel brake and which, on the basis of a given value, controls an actuator for actuating the wheel brake (12b, 14b, 16b, 18b), characterised in that the actuator comprises an electric motor (M1H) and a locking arrangement, in particular a disengaging arrangement (Ku1), wherein, for the purpose of actuating the wheel brake via the electric motor, the locking arrangement is first of all released, and the said locking arrangement is closed again after actuation has been terminated.

2. Electromechanical braking system for a motor vehicle, having at least two control units (12a, 14a, 16a, 18a) which are associated with at least two wheel brakes and are supplied with power by different power supply systems and which, on the basis of given values, control actuators for actuating the wheel brakes (12b, 14b, 16b, 18b), characterised in that the actuator has an additional resetting facility (M1R) which, in the event of a fault at one wheel brake, is actuated by the control unit of another wheel brake.

3. Braking system according to one of the preceding claims, characterised in that each control unit carries out regulation of the braking force or braking moment, wherein a regulating intervention takes place if the deviation between the given value and the actual value exceeds a predetermined limit value, or if the change in the deviation exceeds a limit value, and wherein the locking arrangement is first of all released and then the electric motor is triggered in proportion to the deviation.

4. Braking system according to claim 3, characterised in that, if both conditions are not fulfilled, the triggering of the locking arrangement is terminated and the electric motor switched so as to be devoid of current.

5. Braking system according to one of the preceding claims, characterised in that the control unit contains a microcomputer system which is checked for faults, and triggering of the electric motor and of the locking arrangement is possible only in the case of fault-free operation.

6. Braking system according to one of the preceding claims, characterised in that, in the case of a fault which prevents releasing of the brake, the regulating operation is discontinued and release takes place via the additional resetting arrangement.

7. Braking system according to one of the preceding claims, characterised in that a fault which prevents releasing of the brake is ascertained on the basis of the braking moment or braking force measured.

8. Braking system according to one of the preceding claims, characterised in that the fault information is evaluated in a further unit which is in communication both with the control unit of the actuator affected by the fault and also with the control unit for the resetting arrangement, and which conveys to the latter the command for triggering.

9. Braking system according to claim 8, characterised in that the electric motor and resetting arrangement are supplied with power by different power supply systems.

10. Any of the braking systems substantially as hereinbefore described with reference to the accompanying drawings.